

ferronyl™ iron supplement

introduction

Iron deficiency continues to be a concern around the world, especially in women and children, often resulting in anemia.¹ One approach to prevent iron deficiency is supplementation of food, vitamins, and nutritional products.² When selecting an iron source for supplementation it is important to consider bioavailability, toxicity, potential side effects, iron content, taste and ease of formulation. Ferronyl™ iron supplement is an ideal source of essentially pure iron with minimal metallic taste and excellent bioavailability demonstrated in preclinical studies.^{3,4,5} Thus, it is the better choice for iron supplementation formulators.^{6,7}

Ferronyl™ iron supplement powder is elemental iron (Fe) with high (> 98%) iron content. High iron content enables lower use levels to achieve the same daily intake levels compared with ferrous (Fe²⁺) salts (e.g., ferrous sulfate, ferrous fumarate or ferrous gluconate). This is important in multivitamin formulations where smaller tablets are preferred to encourage consumer use, but are often difficult to achieve with the large number of actives in a formulation.

In addition to the high iron content, a key physical property of Ferronyl™ iron supplement is its fine spherical particle morphology that results in higher bioavailability in preclinical trials than other elemental iron forms.^{3,4}

With its low use level and excellent bioavailability, Ferronyl™ iron supplement is a better choice for iron supplementation, in:

- multivitamin and iron supplement tablets;
- sprinkle packs;
- chewable vitamin tablets; and
- liquid suspensions.

benefits of ferronyl™ iron supplement

- low use levels
- higher bioavailability
- easy to formulate
- generally recognized as safe (GRAS)

physical and chemical properties

product description

Ferronyl™ iron supplement is elemental iron manufactured by the chemical decomposition of iron pentacarbonyl. The resulting iron particles are small, uniform spheres of high purity with only traces of carbon, oxygen and nitrogen.

chemical description	elemental iron
CAS registry number:	7439-89-6
CAS registry name:	iron
chemical formula	Fe
synonyms	carbonyl iron, carbonyl iron powder (CIP)

iron content

With greater than 98% iron, Ferronyl™ iron supplement has a much higher iron level than ferrous salts, such as ferrous gluconate, ferrous sulfate and ferrous fumarate (table 1). As a result, substantially less Ferronyl™ iron supplement is required to reach the same unit dose than a ferrous salt, resulting in lower tablet weight. This makes Ferronyl™ iron supplement well suited for multivitamin applications with high active levels, as Ferronyl™ iron supplement can reduce tablet weight.

table 1: Ferronyl™ iron supplement required to reach same unit dose compared with other iron sources.

	ferronyl™ iron supplement (Fe)	ferrous gluconate (C ₁₂ H ₂₂ O ₁₉ Fe)	ferrous gluconate (C ₄ H ₂ FeO ₄)	ferrous gluconate (FeSO ₄)
iron percentage	98	12	32	36
molecular weight	56	446	170	152
amount of iron supplement needed to meet US DRV†,8,9	18.4 mg	150.0 mg	54.4 mg	50.0 mg

†Daily Recommended Value (DRV) for adult males is 8 mg/day and for adult females is 18 mg/day.

particle morphology

Ferronyl™ iron supplement is a grey powder. When examined under a scanning electron microscope (SEM), Ferronyl™ iron supplement is highly spherical (figure 1).

particle size and particle size distribution

Ferronyl™ iron supplement has a narrow particle size distribution (figure 2). The typical average particle size is about 7 to 9 microns which is smaller than the 10-100 microns of other forms of elemental iron (e.g., reduced, electrolytic and atomized; see table 3). This small particle size contributes to its high bioavailability.

With a narrow particle size distribution, Ferronyl™ iron supplement does not require additional processing prior to formulation. Other iron sources can have wide particle size distributions and, thus, must be sieved, milled or ground prior to use, adding time and cost to the manufacturing process.

figure 1: Ferronyl™ iron supplement particles are spherical, providing good flow properties.

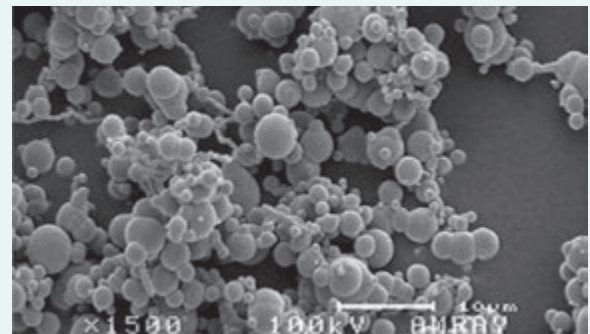
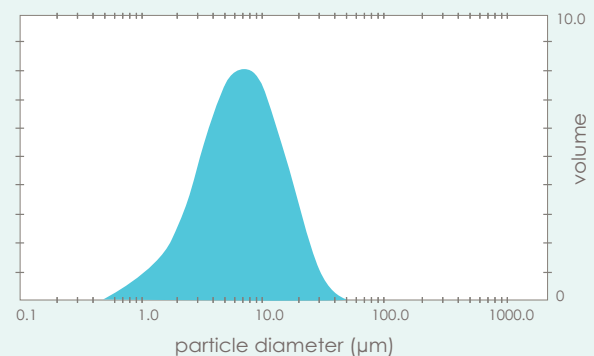


figure 2: Ferronyl™ iron supplement iron has a narrow particle size distribution and small particle size.

typical average particle size = 7-9 µm



bioavailability in preclinical trials

The amount of iron absorbed by the body per unit dosage from a particular iron source is a function of several factors — particle size, surface area, ionic charge and iron content. The first three of these factors contribute to the relative biological value (RBV) of the iron source — a measure of how quickly the iron enters the blood stream. The iron content is a function of molecular structure, e.g., elemental iron versus ferrous salts like ferrous sulfate (FeSO₄) and is a measure of the percentage of iron in a unit dose. Multiplying the RBV by the iron content produces the iron absorption per unit dosage. Table 3 shows that the high iron absorption from Ferronyl™ iron supplement results from its small particle size, which contributes to a higher RBV than other forms of elemental iron, and its high iron content relative to ferrous sulfate. A study of iron-deficient rats,⁵ concluded that, for similar iron dosage levels, carbonyl iron powder was as effective as ferrous sulfate and more so than ferrous pyrophosphate in restoring normal hematocrit levels (table 4). As a result of its finer particle size, carbonyl iron powder was also found to be more efficacious than the other forms of elemental iron (e.g., electrolytic or reduced).

table 3: The small particle size of Ferronyl™ iron supplement contributes to its high RBV, which together with its high iron content leads to high absorption per unit dose.^{5,10}

iron source	particle size, μm	RBV, %	iron content, %	absorption
FeSO ₄ [‡]	N/A	100	20	20
reduced iron	10-20	34	96	33
electrolytic iron	10-20	48	97	47
ferronyl™ iron supplement	7-9	70	98	69

[‡]FeSO₄·4H₂O

table 4: Effect of various iron supplements on rat hematocrit levels.⁵

iron source	supplement dose (mg/kg)	iron dose (mg/kg)	increase in hematocrit with 2 weeks supplementation
control (basal diet)	0	0	-2
FeSO ₄	30	6	4
FeSO ₄	60	12	11
FeSO ₄	120	24	22
ferronyl™ iron supplement	12	12	6
ferronyl™ iron supplement	24	24	15

applications

As Ferronyl™ iron supplement is easily formulated into tablets and liquid suspensions, it is a better choice for iron supplements, including multivitamin tablets, chewable tablets, sprinkle packs and liquid suspensions.

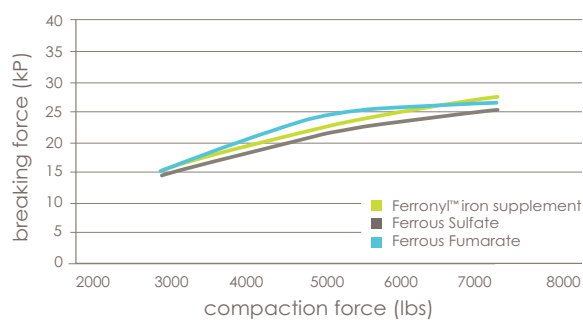
One advantage of formulating with Ferronyl™ iron supplement is that it does not require further processing prior to formulation, thus reducing manufacturing time and costs. With its narrow particle size distribution and spherical particle morphology, Ferronyl™ iron supplement can be formulated as supplied.

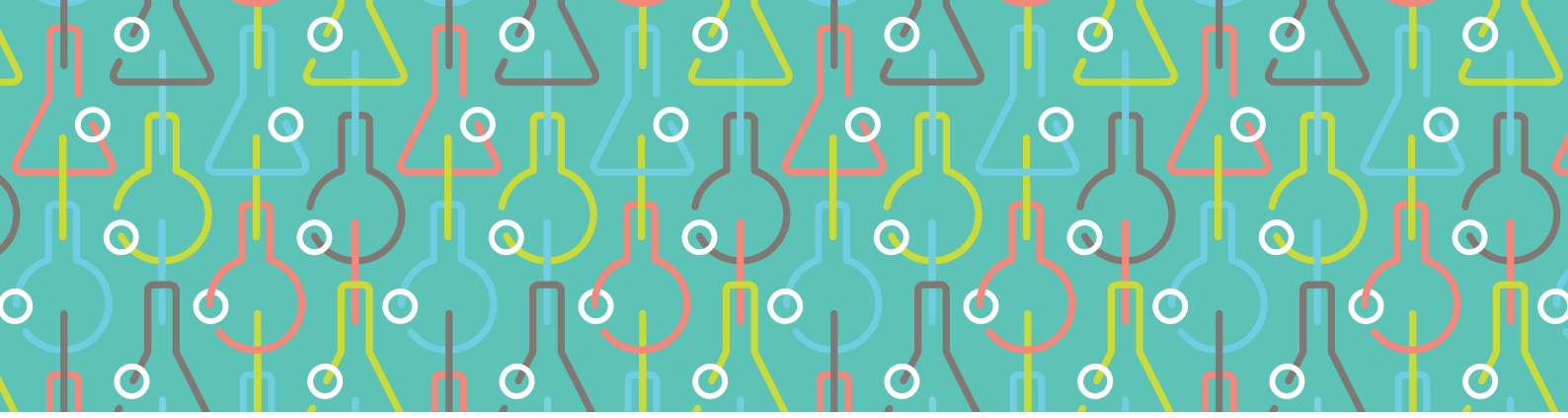
tablets

Because less Ferronyl™ iron supplement is required to achieve the unit dose, compared to ferrous salts, smaller tablets are often achieved. Hence, Ferronyl™ iron supplement is ideally suited for multivitamin formulations containing iron to reduce tablet weight compared to ferrous salts. High tablet weight can lead to difficult to swallow tablets. In compaction studies,

tablets of equivalent weight containing the DRV of various forms of iron for adults with equal parts lactose and dicalcium phosphate and small amounts of lubricant were evaluated for breaking force and friability over a range of compaction forces. Ferronyl™ iron supplement provided tablets of equivalent hardness and friability to ferrous sulfate and ferrous fumarate (figure 3).

figure 3: Ferronyl™ iron supplement provides tablets of similar hardness to tablets with ferrous sulfate or ferrous fumarate.





sprinkle packs

As a great example of synergy, we have brought together the ingredient processing expertise of Pharmachem and the Ferronyl™ iron supplement from Ashland to create a new product with additional features. Ferronyl™ iron supplement is specially processed, combined with flavor and put into a stick pack. This new sprinkle pack formula disperses quickly on the tongue and is easy to swallow. The small package controls dosage and is portable. This product can be a great alternative for consumer populations that have difficulty swallowing tablets, like children and seniors.

As an example, a 1.5 gram sprinkle pack contains 9 mg of Ferronyl™ iron supplement, with vitamin B12, folic acid, silica and natural flavors and sweeteners. However, custom sprinkle packs can be formulated to a variety of specifications.

references

1. Zhu Q, Qian Y, Yang Y, et al. Effects of carbonyl iron powder on iron deficiency anemia and its subchronic toxicity. *J. Food Drug Anal.*, 24, 746–753, 2016.
2. Gordeuk VR, Brittenham GM, McLaren CE, et al. Carbonyl iron therapy for iron deficiency anemia. *Blood*, 67(3),745–752, 1986.
3. Lynch SE and Bothwell T. A Comparison of physical properties, screening procedures, and a human efficacy trial for predicting the bioavailability of commercial elemental iron powders used for food fortification. *Int. J. Vitam. Nutr. Res.*, 77(2), 107–124, 2007.
4. Huebers HA, Brittenham GM, Csiba E, et al. Absorption of carbonyl iron. *J. Lab. Clin. Med.*, 108, 473–478, 1986.
5. Sacks PV and Houchin DN. Comparative bioavailability of elemental iron powders for repair of iron deficiency anemia in rats. Studies of efficacy and toxicity of carbonyl iron. *Am. J. Clin. Nutr.*, 31, 566–573, 1978.
6. Gordeux VR, Brittenham GM, Hughes MA et al. Carbonyl Iron for short-term supplementation in female blood donors. *Transfusion*, 27, 80–85, 1987.
7. Gordeaux VR, Brittenham GM, Bravo J, et al. Prevention of iron deficiency with carbonyl iron in female blood donors. *Transfusion*, 30, 239–245, 1990.
8. US Food & Drug Administration. Factsheet. FDA Vitamins and Minerals Chart. https://www.accessdata.fda.gov/scripts/InteractiveNutritionFactsLabel/factsheets/Vitamin_and_Mineral_Chart.pdf. Accessed 12 February 2018.
9. National Institutes of Health. Dietary Supplement Label Database. <https://www.dslid.nlm.nih.gov/dslid/dailyvalue.jsp>. Accessed 12 February 2018.
10. Pla GW, Fritz JC, and Rollinson CL. Relationship between the biological availability and solubility rate of reduced iron. *J. AOAC*, 59(3), 582–583, 1976.

regional centers

North America —
Wilmington, DE USA
Tel: +1 877 546 2782

Europe — Switzerland
Tel: +41 52 560 55 00

India — Maharashtra
Tel: +91 22 6148 4646

Asia Pacific — Singapore
Tel: +65 6775 5366

Middle East, Africa —
Istanbul, Turkey
Tel: +00 90 216 538 08 00

Latin America — Mexico
Tel: +52 55 52 76 6121

ashland.com/contact

® Registered trademark, Ashland or its subsidiaries, registered in various countries

™ Trademark, Ashland or its subsidiaries, registered in various countries

© 2018, Ashland / FNB18-103

The information contained in this brochure and the various products described are intended for use only by persons having technical skill and at their own discretion and risk after they have performed necessary technical investigations, tests and evaluations of the products and their uses. Certain end uses of these products may be regulated pursuant to rules or regulations governing medical devices, drug uses, or pesticidal or antimicrobial uses. It is the end user's responsibility to determine the applicability of such regulations to its products.

All statements, information, and data presented herein are believed to be accurate and reliable, but are not to be taken as a guarantee of fitness for a particular purpose, or representation, express or implied, for which seller assumes legal responsibility. No freedom to use any patent owned by Ashland, its subsidiaries, or its suppliers is to be inferred.